Chapter 8: Conservation of Energy

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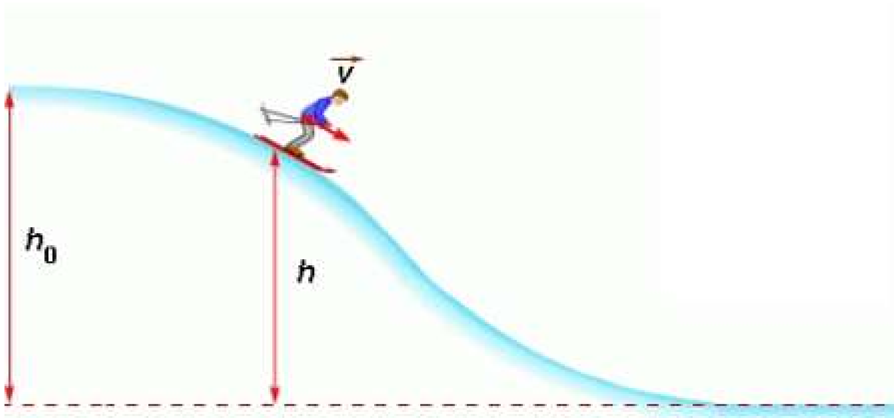


Outline

8.4 Changes in Mechanical Energy for Nonconservative Forces

$$\Delta E_{\text{mech}} = \Delta K + \Delta U_g = -f_k d = -\Delta E_{\text{int}}$$

In general, if a nonconservative force acts within an isolated system,

$$\Delta K + \Delta U + \Delta E_{\text{int}} = 0$$

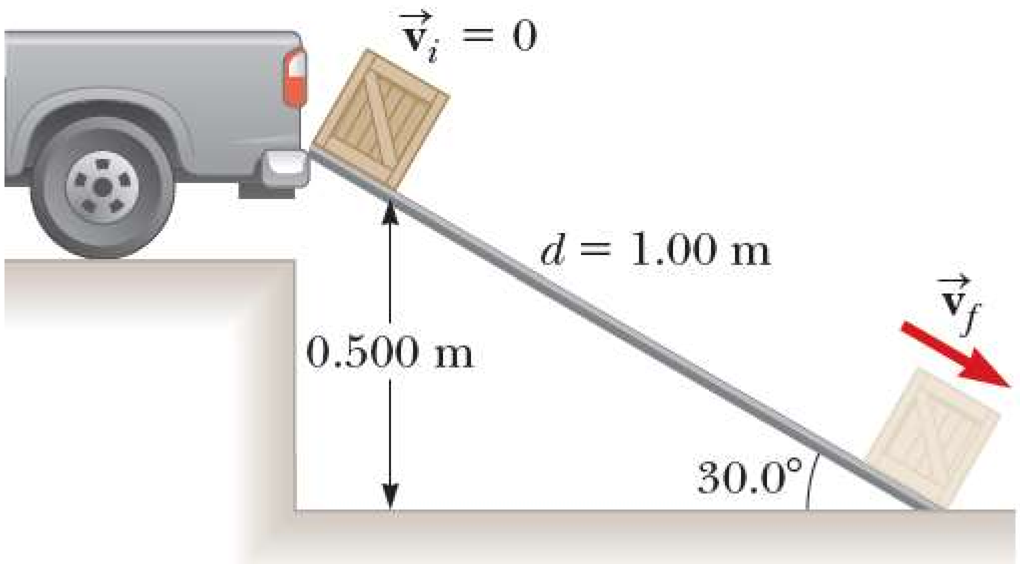
If the system in which nonconservative forces act is nonisolated and the external influence on the system is by means of work, the generalization:

$$\sum W_{\text{other forces}} - f_k d = \Delta E_{\text{mech}}$$

$$\sum W_{\text{other forces}} = W = \Delta K + \Delta U + \Delta E_{\text{int}}$$

Example 8.7 Crate Sliding Down a Ramp

A 3.00-kg crate slides down a ramp. The ramp is 1.00 m in length and inclined at an angle of 30° as shown. The crate starts from rest at the top, experiences a constant friction force of magnitude 5.00 N, and continues to move a short distance on the horizontal floor after it leaves the ramp.



$$\Delta K + \Delta U + \Delta E_{\text{int}} = 0$$

$$\left(\tfrac{1}{2}mv_f^2 - 0\right) + \left(0 - mgy_i\right) + f_k d = 0$$

$$v_f = \sqrt{\frac{2}{m}\left(mgy_i - f_k d\right)}$$

$$v_f = \sqrt{\frac{2}{3.00\text{ kg}}\left[\,3.00\text{ kg}\;(9.80\text{ m/s}^2)(0.500\text{ m}) - (5.00\text{ N})(1.00\text{ m})\right]}$$

$$= 2.54\text{ m/s}$$

(B) How far does the crate slide on the horizontal floor if it continues to experience a friction force of magnitude 5.00 N?

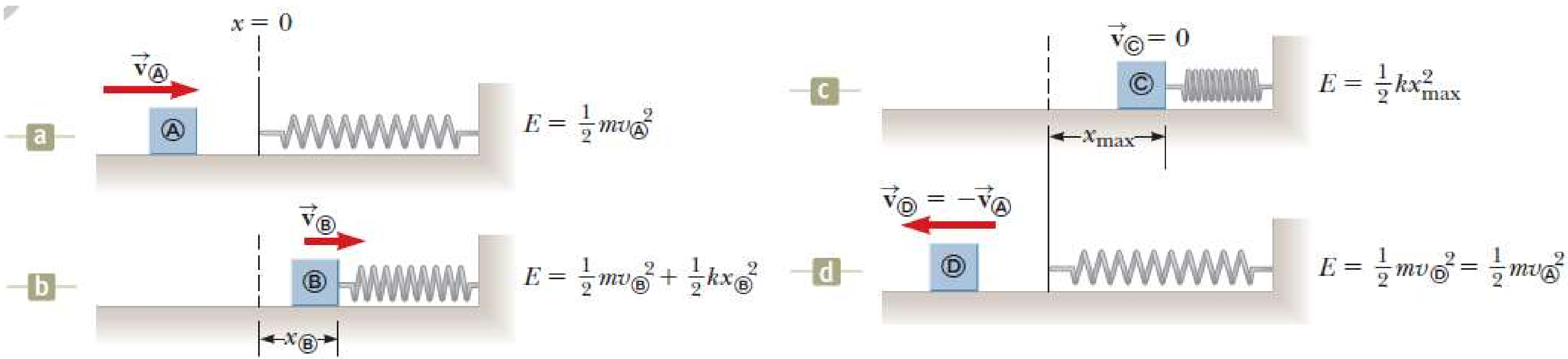
$$\Delta K + \Delta E_{\text{int}} = 0$$

$$(0 - \tfrac{1}{2}mv_i^2) + f_k d = 0$$

$$d = \frac{mv_i^2}{2f_k} = \frac{(3.00\ \text{kg})(2.54\ \text{m/s})^2}{2(5.00\ \text{N})} = 1.94\ \text{m}$$

Example 8.8 Block-Spring Collision

A block having a mass of 0.80 kg is given an initial velocity v_A = 1.2 m/s to the right and collides with a spring whose mass is negligible and whose force constant is k = 50 N/m as shown. (a) Assuming the surface to be frictionless, calculate the maximum compression of the spring after the collision. (b) Suppose a constant force of kinetic friction acts between the block and the surface, with μ_k = 0.50. If the speed of the block at the moment it collides with the spring is v_A = 1.2 m/s, what is the maximum compression x_C in the spring?



$$\Delta K + \Delta U = 0$$

$$(0 - \tfrac{1}{2}mv_{Ⓐ}^2) + (\tfrac{1}{2}kx_{max}^2 - 0) = 0$$

$$x_{max} = \sqrt{\frac{m}{k}}\,v_{Ⓐ} = \sqrt{\frac{0.80\text{ kg}}{50\text{ N/m}}}(1.2\text{ m/s}) = 0.15\text{ m}$$

$$f_k = \mu_k n = \mu_k mg$$

$$\Delta K + \Delta U + \Delta E_{int} = 0$$

$$(0 - \tfrac{1}{2}mv_{Ⓐ}^2) + (\tfrac{1}{2}kx_{Ⓒ}^2 - 0) + \mu_k mgx_{Ⓒ} = 0$$

$$kx_{Ⓒ}^2 + 2\mu_k mgx_{Ⓒ} - mv_{Ⓐ}^2 = 0$$

$$50x_{Ⓒ}^2 + 2(0.50)(0.80)(9.80)x_{Ⓒ} - (0.80)(1.2)^2 = 0$$

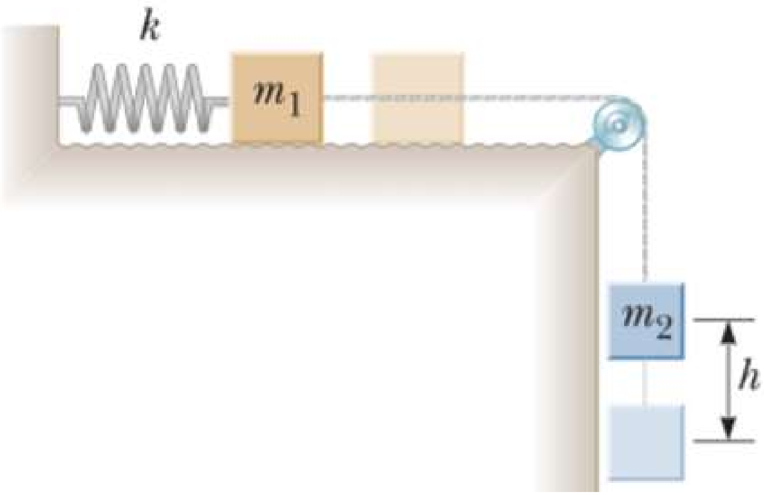
$$50x_{Ⓒ}^2 + 7.84x_{Ⓒ} - 1.15 = 0$$

$x_{Ⓒ} = 0.092$ m and $x_{Ⓒ} = -0.25$ m

The physically meaningful root is $x_{Ⓒ} = 0.092$ m

Example 8.9 Connected Blocks in Motion

Two blocks are connected by a light string that passes over a frictionless pulley as shown in the figure. The block of mass m_1 lies on a horizontal surface and is connected to a spring of force constant k. The system is released from rest when the spring is unstretched. If the hanging block of mass m_2 falls a distance h before coming to rest, calculate the coefficient of kinetic friction between the block of mass m_1 and the surface.



$$(1) \quad \Delta U_g + \Delta U_s + \Delta E_{\text{int}} = 0$$

$$(0 - m_2 gh) + \left(\tfrac{1}{2}kh^2 - 0\right) + f_k h = 0$$

$$-m_2 gh + \tfrac{1}{2}kh^2 + \mu_k m_1 gh = 0$$

$$\mu_k = \frac{m_2 g - \frac{1}{2}kh}{m_1 g}$$

8.5 Power

The time rate at which work is done by a force is said to be the power due to the force. If a force does an amount of work W in an amount of time Δt, the average power due to the force during that time interval is:

$$\overline{\mathcal{P}} \equiv \frac{W}{\Delta t}$$

Thus, while the same work is done in rolling the refrigerator up both ramps, less power is required for the longer ramp.

In a manner similar to the way we approached the definition of velocity and acceleration, we define the instantaneous power *P* as the limiting value of the average power as Δt approaches zero:

$$\mathcal{P} \equiv \lim_{\Delta t \to 0} \frac{W}{\Delta t} = \frac{dW}{dt}$$

The instantaneous power can also be written as,

$$\mathscr{P} = \frac{dW}{dt} = \mathbf{F} \cdot \frac{d\mathbf{r}}{dt} = \mathbf{F} \cdot \mathbf{v}$$

In general, power is defined for any type of energy transfer. Therefore, the most general expression for power is

$$\boldsymbol{P = \frac{dE}{dt}}$$

The SI unit of power is the joule per second. This unit is used so often that it has a special name, the watt (W), after James Watt.

$$1\ \mathrm{W} = 1\ \mathrm{J/s} = 1\ \mathrm{kg \cdot m^2/s^3}$$

Example 8.11 Power Delivered by an Elevator Motor

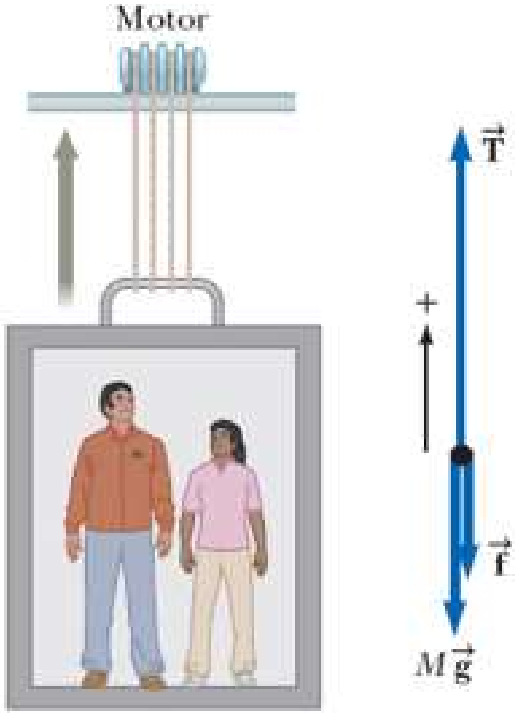
- A 1000-kg elevator carries a maximum load of 800 kg. A constant frictional force of 4000 N retards its motion upward. What minimum power must the motor deliver to lift the fully loaded elevator at a constant speed of 3 m/s?

$$F_{net} = ma_y$$

$$T - f - Mg = 0$$

$$T = f + Mg = 4000 + 1800 \times 9.8$$
$$= 21640 \text{ N}$$

$$P = T\vartheta = 21640 \text{ N} \times 3 \text{ m/s}$$
$$= 6.48 \text{ kW}$$



(B) What power must the motor deliver at the instant the speed of the elevator is v if the motor is designed to provide the elevator car with an upward acceleration of 1.00 m/s²?

$$\sum F_y = T - f - Mg = Ma$$

$$T = M(a + g) + f$$

$$P = Tv = [M(a + g) + f]v$$

$$P = [(1\,800 \text{ kg})(1.00 \text{ m/s}^2 + 9.80 \text{ m/s}^2) + 4\,000 \text{ N}]v$$

$$= (2.34 \times 10^4)v$$

- A nonisolated system
- An isolated system
- Conservation of energy equations
- The instantaneous power

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